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TRACKING EVOLUTION OF ELECTRIC VEHICLES AND NEW MOBILITY TECHNOLOGY

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U.S. DEPARTMENT OF ENERGY
Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

OVERVIEW

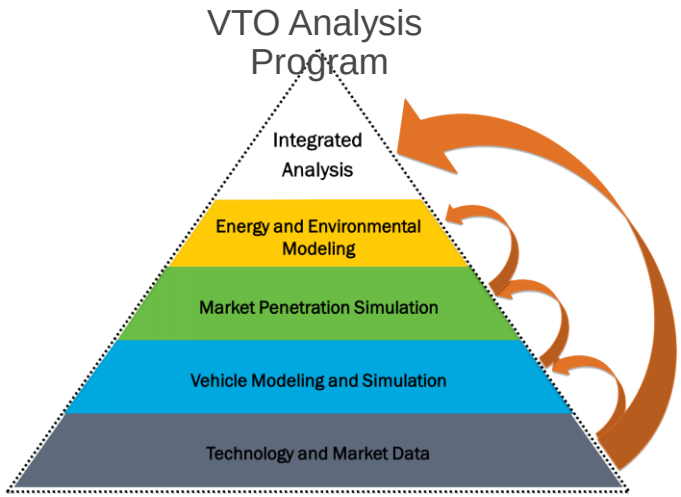
Timeline	Barriers
• Project start date: 10/01/2019 • Project end date: 09/30/2020 • Percent complete: 70%	• Provide quality data and information regarding electrification and new mobility technologies • Provide both quick responses to internal and external queries and develop summary reports to VTO
Budget	**Partners/Collaborators**
• Funding for FY19: $50 K • Funding for FY20: $200 K	• National labs: ORNL provides EV data

RELEVANCE AND OBJECTIVES

To better inform VTO analysis, analysis-supported activities, and associated stakeholders

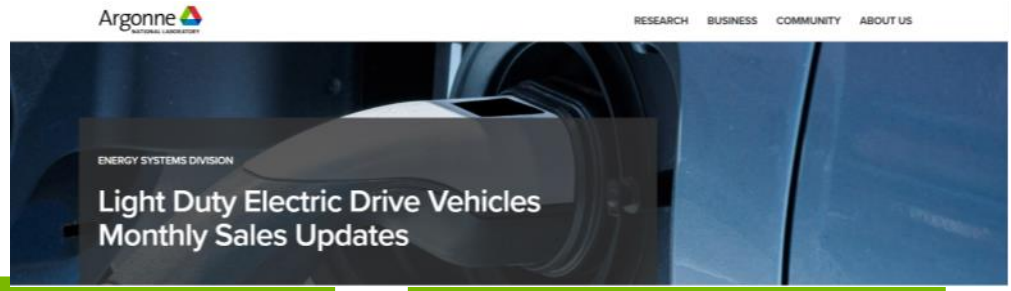
Objectives: Synthesize and improve upon data for electrification and mobility technologies to evaluate the impacts of these new technologies.

- **Monthly E-drive Sales Summary,** by make, model and OEM, track technology trends
- **Summarize public announcements** for electric vehicles, new mobility, and connected and automated vehicle (CAV) technologies in the near-future
- **Collect market and usage data** of new mobility technologies, such as e-bike, e-scooter, transportation network companies (TNC), and CAV
- **Document national-scale impacts** of plug-in electric vehicles (PEV)
- **Summarize trends** in efficiency, features, capabilities, and technologies of electric vehicles from advanced vehicle test data both in-lab and on-road
- **Track battery supply-chain**



APPROACH

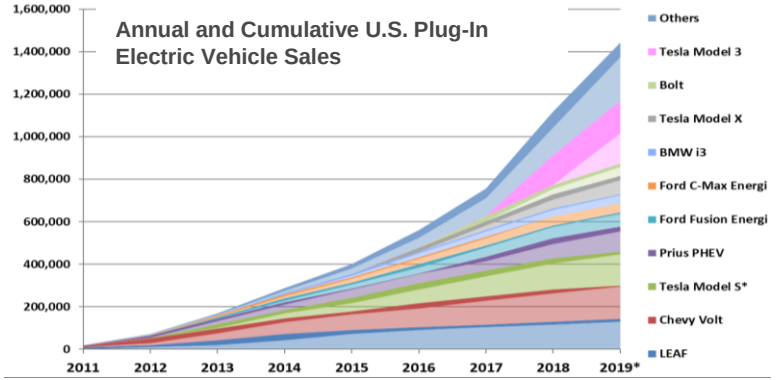
Data time-series back to 1999

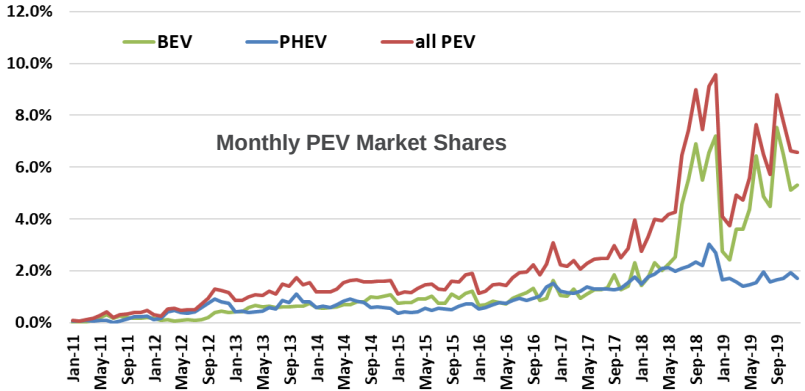


Topic	Method	Deliverables
• **E-drive and Mobility Technologies**	• **Collect** sales, stock, efficiency data from databases, literature, news, testing etc.	• Monthly E-drive summary (Excel files)
• **Track E-drive projections**	• **Analyze** usage characteristics	• Argonne webpage
• **Track Battery Supply-chain**	• **Track and summarize** market trends and technology evaluation	• Public facing reports
• **EV Efficiency Characterization**	• **Quantify** energy/emission impacts at national and regional level	• Selected results for Transportation fact of the week
		• Presentations to DOE

ACCOMPLISHMENTS: E-DRIVE VEHICLE SALES BY MAKE AND MODEL, AND MARKET TREND

Monthly summary report shared with DOE and public subscribers





Monthly/Quarterly E-drive Summary

- BEV, PHEV, FCEV and HEV
- Monthly and annually E-drive sales by make/model
- Cumulative sales
- Market shares
- Sales shares by OEM
- Sales shares by EPA size class
- Sales weighted efficiency and range
- Sales variation with gasoline price
- Comparison of sales since introduction (of top-selling models)

More contents to be found in our monthly and quarterly reports, please contact yzhou@anl.gov for details

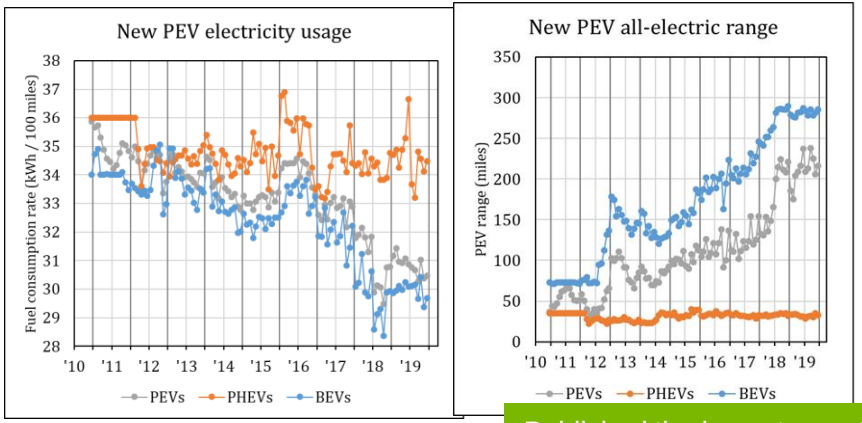
ACCOMPLISHMENTS: PEV TECHNOLOGY AND MARKET TREND AND RESULTING IMPACT

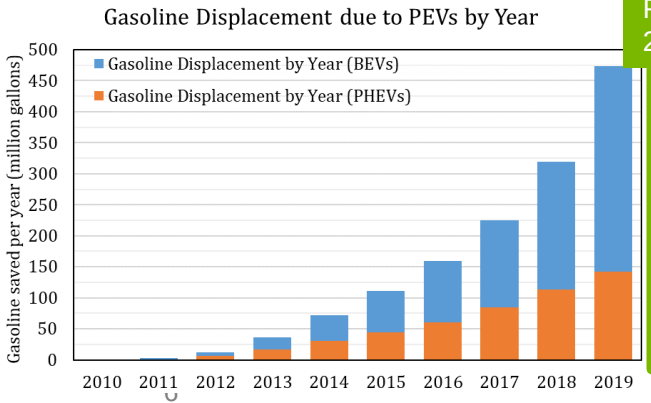
PEV Assessment Report
(Annually published)

Aggregate Impact
- Electric miles traveled
- Gasoline replaced
- Carbon emission reduction
- Electricity consumption

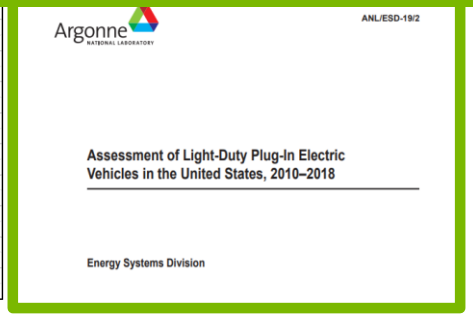
Vehicle Characteristics
- Electric range
- Electric efficiency
- Vehicle manufacturing and assembly
- Vehicle price
- Battery capacity and cathode chemistry

PEV range is increasing and energy efficiency is improving





Published the impact report in 2019. 2020 report coming soon



"Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2019."Argonne National Laboratory, 2020, draft submitted to HQ

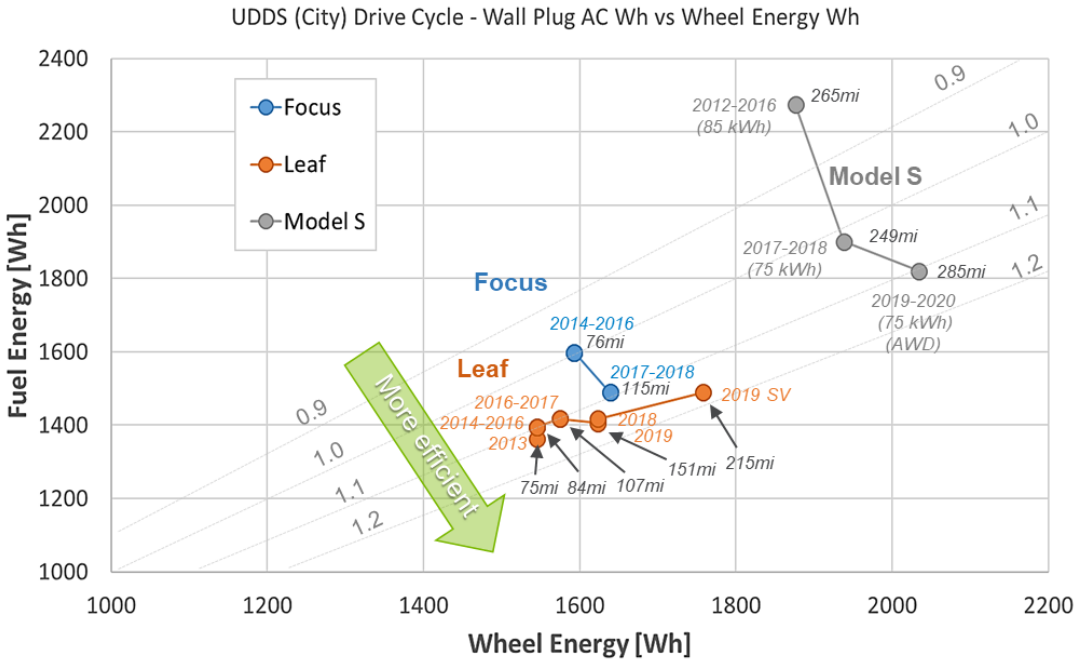
ACCOMPLISHMENTS: INSIGHTS FOR VTO IN ELECTRIFICATION EFFICIENCY

Analysis of MY 2012-2020

- Wheel energy vs consumed energy
- City vs Highway Efficiency
- Coefficient of Rolling Resistance vs Aerodynamic forces
- Tracking model changes over time
  - Range vs Battery vs Efficiency

Conclusions

- Extra battery weight increases wheel energy
- Powertrain efficiency suffered in those models that only increased battery size *(e.g., i3, not shown in graph)*
- Most models increased range improving BOTH efficiency and battery size
- Tesla included many improvements, but most interestingly, switch to AWD
  - Adding PM motor for main drive vs AC ind



COLLABORATION AND PROPOSED RESEARCH

Collaboration

- Argonne conducts all the data collection and analysis
- ORNL provides monthly vehicle sales from Wards' Auto

Proposed Research *(Note: Any proposed future work is subject to funding levels)*

- Continue the effort **collecting available data** and information
  - E-drive vehicle sales and new mobility technology trends at the national level
- Quantify **national impacts** and publish **public-facing documents**
  - Quantify energy and emissions impacts
  - Document technology evolution trends
  - Annually update the reports
- Quantify **regional impacts** of electrification: a state by state comparison
  - Difference in PEV models adopted at regional level
  - Energy and emission impacts due to the regional difference

SUMMARY

- **Objectives:** synthesize and improve upon data for electrification and mobility technologies to evaluate the impacts of these new technologies.
- **Outcomes:** better inform VTO analysis, analysis-supported activities, associated stakeholders and general public.
- **Methods:** collects data from different databases, literature, and testing results, and summarize the market and technology trends.
- **Results:** documented in the Excel file and public-facing documents for DOE and general subscribers of these monthly and yearly reports.
- **Other Publications:** Selected data are published on the Argonne website, and DOE/VTO Transportation facts of the week
- **Milestones:** Successful monthly, quarterly, and annual milestones delivered on-time and within budget – improving over time with more data becomes available

TECHNICAL BACKUP SLIDES

APPROACH – HIGH FIDELITY EV CHARACTERIZATION

Making sense out of "EV Efficiency"

Motivation

- "Efficiency" is nebulously associated with:
  - Chassis efficiency
  - Powertrain efficiency
  - Range achievements
- Public data sources can be used to disentangle vehicle losses from powertrain, efficiency achievements
  - EPA dyno coefficients
  - Sec-by-sec cycle calculations of power
  - Compare different models
  - Track year-by-year model changes

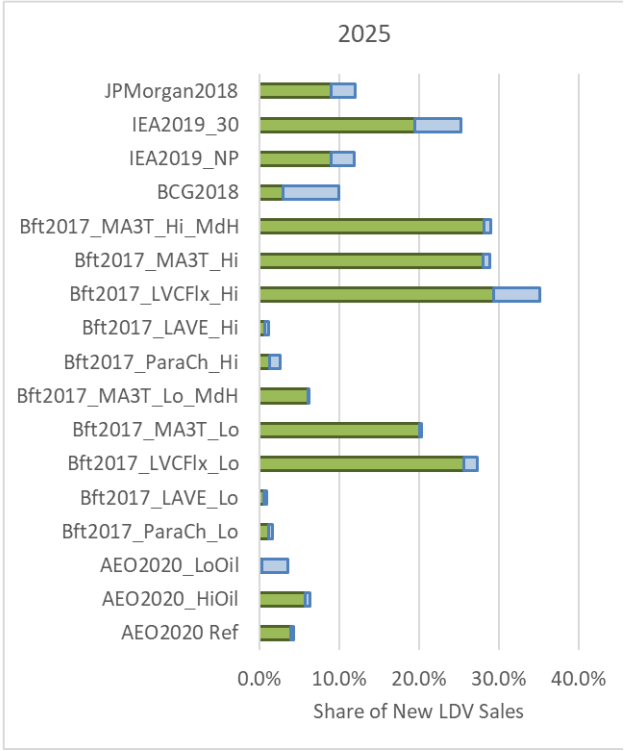
Calculations

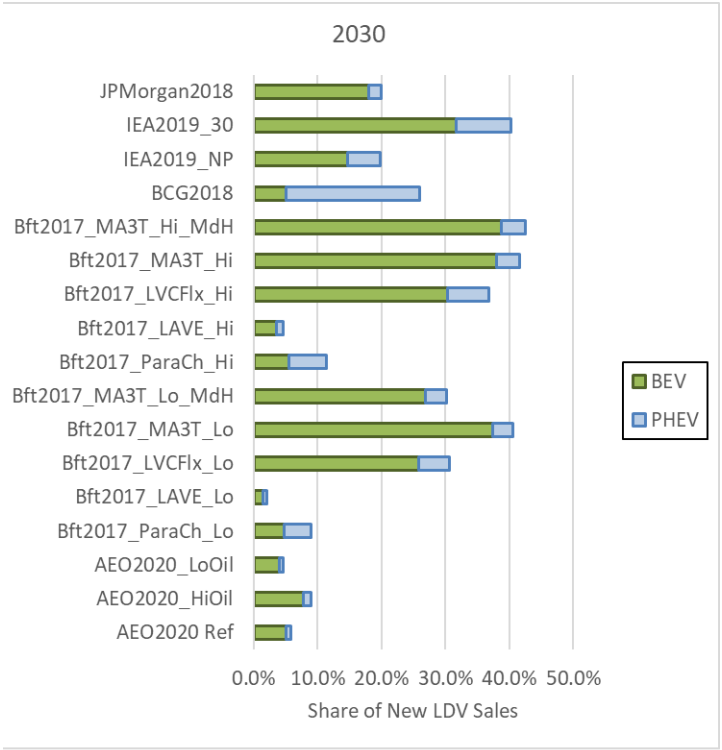
<u>For each EV model from 2012 to 2020</u>

- Drive cycle positive wheel energy / distance = **Vehicle Chassis Demand**
- Drive cycle positive wheel energy / AC Wh consumed = **Powertrain "Efficiency"**
- **Infer rolling resistance**
- **Vehicle driving force** (at highway speed)
- *(future)* Usable vs quoted **battery energy**
- *(future)* **Charger efficiency,** which contributes to "Powertrain Efficiency"

ACCOMPLISHMENTS: PROJECTIONS OF THE U.S. PEV MARKET SHARE VARY FROM 3% TO 40% IN 2030

Most studies project more BEV than PHEV in the future



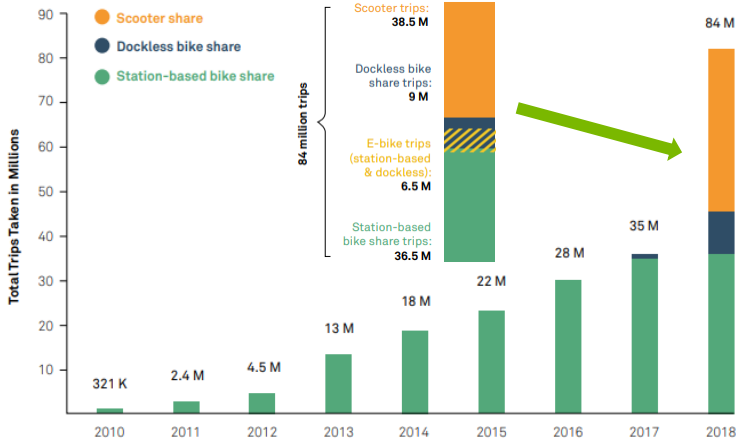


ACCOMPLISHMENTS: TOTAL TRIPS AND TRIP CHARACTERISTICS BY MICRO-MOBILITY

In 2018, total 84 millions trips in the U.S.

- 36.5 million trips on station-based bike
- 38.5 million trips on shared e-scooters
- 6.5 million trips on E-bikes (6 million on dockless and 500,000 on station-based systems).
- Cumulatively, 207 million trips have been taken on shared bikes and e-scooters

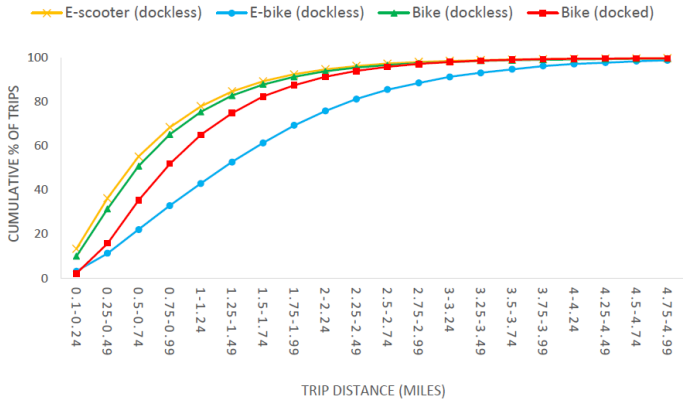
Annual Total Trips Traveled



Average trip distance and time (from several cities)

- Scooter: 1-1.5 miles
- Station-based bike: 1- 3 miles
- Dockless E-bike: 1-2 miles
- Travel time varies by mode: 10-25 minutes

Trip distance by shared mode
(Washington D.C. as an example)

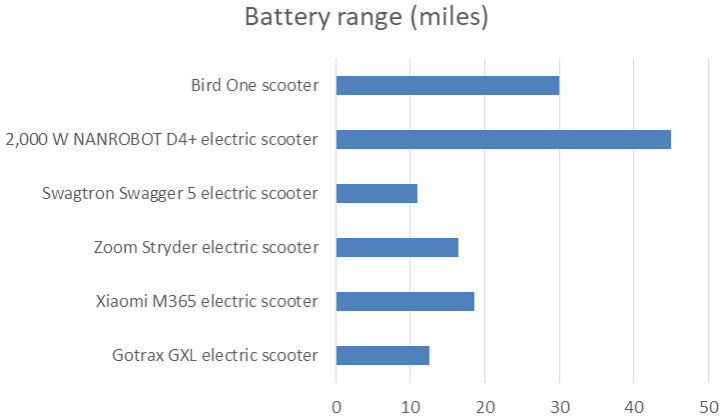


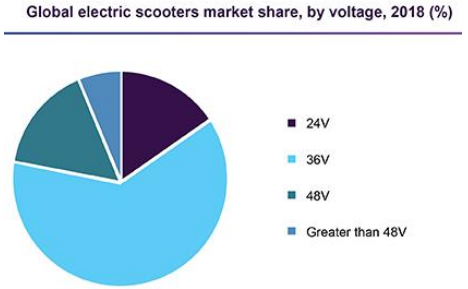
Reference: **Shared-Micromobility in 2018,** https://nacto.org/wp-content/uploads/2019/04/NACTO_Shared-Micromobility-in-2018_Web.pdf

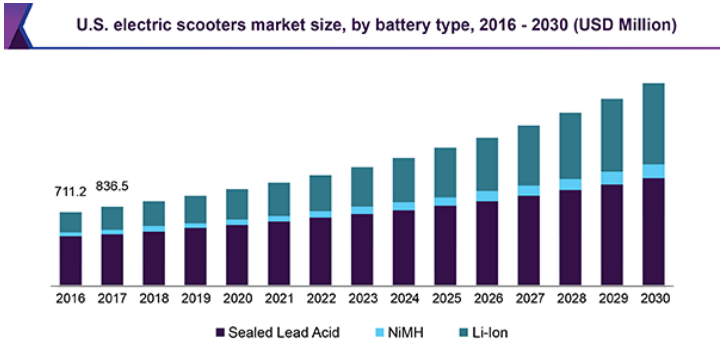
ACCOMPLISHMENTS: E-SCOOTER BATTERY RANGE AND FUTURE DEMAND

36-Volt scooters dominate electric scooters market

- The global market can be categorized by voltage into 24V, 36V, 48V, and > 48V.
- The demand for 48V batteries is increasing since consumers prefer scooters with a long battery range

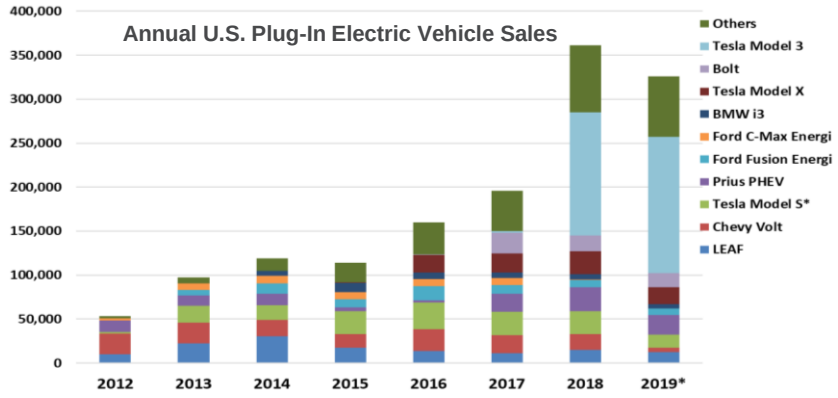




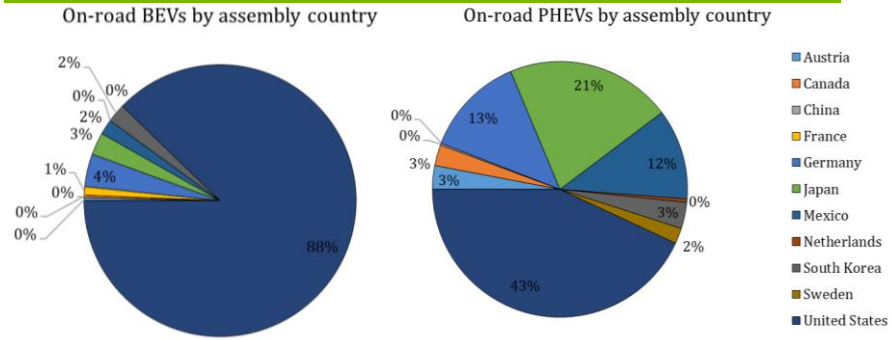


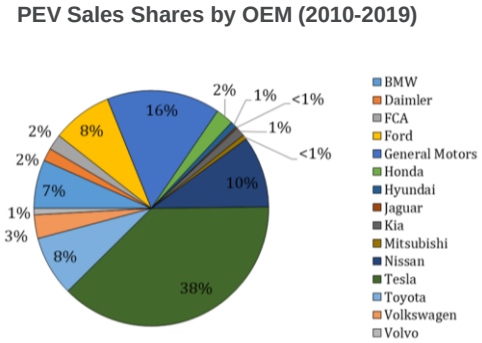
References:
https://www.grandviewresearch.com/industry-analysis/electric-scooters-market
https://electrek.co/2018/10/26/buying-an-electric-scooter/
https://venturebeat.com/2019/05/08/birds-1299-bird-one-scooter-can-travel-30-miles-on-a-charge/

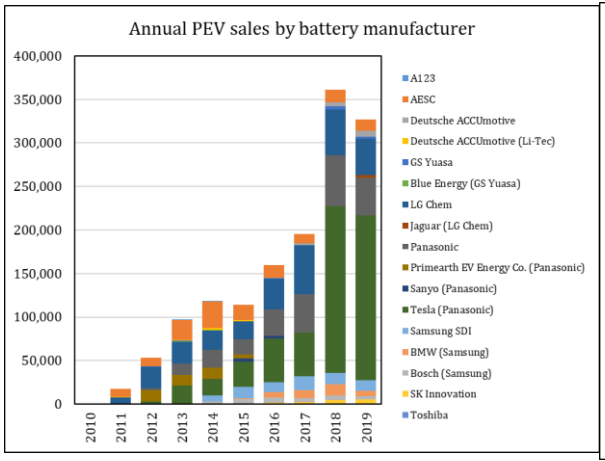
ACCOMPLISHMENTS: TRACK E-DRIVE VEHICLE SALES, SUMMARIZE MARKET AND TECHNOLOGY TREND

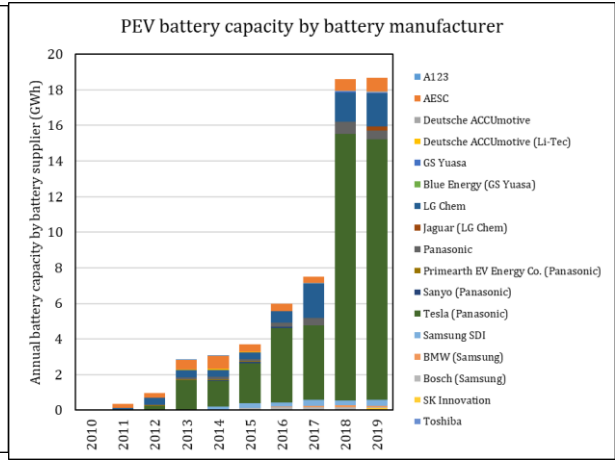


Majority of PEVs sold in the U.S. have been assembled in the United States









REVIEWERS-ONLY SLIDES

CRITICAL ASSUMPTIONS AND ISSUES

- Government agencies or companies from which ANL collects data are improving their data collection and data processing methodologies. But those improvements can cause incompatibility with previous years' data and cause a significant disruption to a historical time series of data.
- Rely on available travel survey information to derive annual vehicle miles traveled and PHEV utility factors when quantifying the gasoline and electricity consumption
- Large EPA vehicle testing databases have some errors so checking and filtering is required.
- EPA full test reports were designed for gasoline vehicles, EV reports are not as complete

PUBLICATIONS

- Gohlke, D. and Y. Zhou. Assessment of Light-Duty Plug-In Electric Vehicles in the United States, 2010–2019. Argonne National Laboratory, 2020, draft submitted to HQ.
- Argonne National Laboratory, Light-Duty Electric Drive Vehicles Monthly Sales Update Program, *https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates*
- Transportation FOTW #1128, April 6, 2020: Innovations in Automotive Battery Cell Composition, https://www.energy.gov/eere/vehicles/articles/fotw-1128-april-6-2020-innovations-automotive-battery-cell-composition
- FOTW #1124, March 9, 2020: U.S. All-Electric Vehicle Sales Level Off in 2019 https://www.energy.gov/eere/vehicles/articles/fotw-1124-march-9-2020-us-all-electric-vehicle-sales-level-2019
- FOTW #1106, November 4, 2019: In the Last Two Months of 2018, U.S. Monthly Sales of All-Electric Vehicles Outpaced Both Plug-in Hybrids and Conventional Hybrids, https://www.energy.gov/eere/vehicles/articles/fotw-1106-november-4-2019-last-two-months-2018-us-monthly-sales-all-electric
- FOTW #1086, June 17, 2019: Seventy-five Percent of Plug-in Vehicles Sold in the United States in 2018 Were Made in the United States, https://www.energy.gov/eere/vehicles/articles/fotw-1086-june-17-2019-seventy-five-percent-plug-vehicles-sold-united-states
- FOTW #1080, May 6, 2019: U.S. Plug-in Vehicles Consumed Nearly Three Terawatt-hours of Electricity in 2018, https://www.energy.gov/eere/vehicles/articles/fotw-1080-may-6-2019-us-plug-vehicles-consumed-nearly-three-terawatt-hours

THANK YOU

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